Background for the Stormwater Management Manual for Western Washington

Introduction:

The state and federal water pollution control statutes require a two-test approach to determining the level of treatment required for any discharge to surface waters. The first test is that all discharges must be treated with the best treatment technology which is economically achievable – regardless of the condition of the receiving water. The state statutes refer to using "all known, available, and reasonable methods of treatment prior to discharge" (Chapter 90.52 RCW). This is referred to as a technology-based requirement. The stated public policy of the federal and state governments is to maintain the highest possible purity of public waters by minimizing pollutant discharges to the extent practicable – as opposed to allowing the maximum tolerable level of pollutant discharge.

The second test is that if there is determined, by scientifically valid methods, to be a potential for the violation of the water quality standards from a discharge, then that discharge must receive water quality-based effluent limits. The effluent limits are to assure the effluent does not cause a violation of the water quality standards. The law does not require 100% certainty but requires a judgment of reasonable potential based on a rational process in order to impose conditions.

The stormwater manual, consistent with federal stormwater regulations, represents a generic, presumptive approach to meeting the technology-based and water quality-based requirements of water pollution control statutes. The presumption is this: The procedures and best management practices outlined in the manual will generally result in compliance with the statutes. The erosion control requirements (Minimum Requirement #2) and BMPs (Volume II), the source control requirement (M.R. #3) and BMP's (Volume IV), and the Oil Control and Basic Treatment Level of the treatment requirement (M.R. #6) are intended to satisfy the technology-based effluent requirements. The Enhanced Treatment Level of the treatment requirement (M.R. #6), the flow duration standard of the flow control requirement (M.R. #7), and the hydroperiod standard of the wetlands protection requirement (M.R. #8) are intended to generically satisfy the water quality-based effluent requirements.

This generic approach to meeting the technology-based and water quality-based requirements of water pollution control laws is intended to handle the vast majority of new and redevelopment projects. There are literally thousands of those projects every year. There aren't sufficient human resources or time to do the type of site-by-site analysis that occurs with municipal sewage treatment and industrial wastewater discharges. However, there are instances where because of the size of a project or the sensitivity of a receiving water, or because of some other regulatory need to ensure compliance with standards (e.g., a certification under section 401 of the Clean Water Act that the discharge will comply with water quality standards), a site-specific stormwater analysis is necessary. In those instances, the appropriate level of treatment identified may be much less, much greater, or about the same as the guidance in the stormwater manual.

In cases where a water quality-based effluent limits for stormwater are assigned, those "effluent limits" do not have to be numerical. In fact, federal rules and policies recommend against assigning effluent limits at this time. What is recommended is the assignment of particular treatment methods that are generally expected to result in compliance with the numeric standards.

This approach probably has been recommended because of the implementation difficulties in determining whether a stormwater discharge may cause a violation of a particular numeric water quality standard. The concentration of a pollutant in a stormwater discharge, the flow rate of that discharge, the concentration of the same pollutant in the receiving water upstream of the discharge, and a critical flow rate of the receiving water are all necessary to perform a mass balance to determine whether a numeric standard will be violated. All of these factors are difficult to determine and can fluctuate somewhat randomly over a wide range of values. So, USEPA, some state water pollution control agencies, and some local governments have each published or adopted stormwater manuals that provide an established process for identifying appropriate prevention, treatment, and flow management practices.

What must also be done is to establish a process to identify whether those practices are achieving their intended goals. The Dept. of Ecology hopes to establish those feedback mechanisms through conditions in NPDES permits that it issues to municipalities. Those permits authorize the discharge of stormwater from municipal storm sewer systems to waters of the State. The permits could also include conditions that require monitoring the physical, chemical, and biological health of natural waters that receive stormwater to see if the ultimate goal of protecting the beneficial uses – including protection and propagation of fish - is achieved.

Flow Control – Minimum Requirement #7

The Standard and its Purpose:

Ecology has provided a flow duration standard as a default standard for use throughout western Washington. It should be used unless a watershed-specific study provides information that indicates a different standard is more appropriate (See "*Western Washington Alternative Requirement*" in Volume I, Chapter 2, page 2-31).

The default standard can be expressed as follows:

> *Match discharge durations of flows from the developed site to the durations of flows from the pre-developed site for the range of pre-development discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow.*
>
> *The pre-developed condition to be matched shall be a forested land cover unless reasonable, historic information is provided that indicates the site was prairie prior to settlement.*

The standard is based on at least three presumptions:

- Above a certain flow rate, it is necessary to match flow durations to prevent accelerated stream channel erosion;
- 50% of a two-year frequency flow is appropriate to use as a generic threshold of significant bedload movement for streams in western Washington
- The most appropriate pre-developed condition to match is that associated with a land cover that predominately existed prior to European settlement of the area.

For background on the first two presumptions, please see the following attachments:

"Rationale for a "Threshold of Concern" in Stormwater Release Rates," Derek Booth, May 2, 1997

Excerpt from the 1998 King County Surface Water Drainage Manual, Section 3.1 "Hydrologic Design Standards and Principles," see pages 3-3 & 3-4.

"Forest Cover, Impervious-Surface Area, and the Mitigation of Stormwater Impacts," Booth et al, Journal of the American Water Resources Association, June 2002

The last article listed above, also provides some criticisms and limitations of the standard.

The third presumption, that of a pre-European settlement land cover condition to establish the flow control target, was inferred as the most appropriate assumption necessary to help achieve the federal and state water pollution statutory and regulatory requirements - to maintain beneficial uses. Stream channel instability in watersheds due to loss of forest cover without the significant influence of land development was noted in field work conducted by King County staff in preparation for developing basin plans (See references to King County 1990a and 1990d, 1991 in Booth, 2002. The King County documents can be provided if necessary). Subsequent HSPF modeling conducted by King County, referred to in Booth 2002, demonstrated the importance of retaining forest cover to maintain channel stability. It also demonstrates the necessity of assuming forested conditions (unless evidence that the area was historically maintained as prairie) as the pre-developed condition to match for sites proposed for development.

This presumption does not acknowledge the periodic influence of fire in changing a watershed's land cover condition and consequently the hydrologic and sediment status of its streams. However, in most areas, the fire-cleared watershed is a periodic, or temporary status. A "developed" (roads, buildings, parks) watershed should be considered a permanent condition. Flow release rates for a developed condition that are targeted to match a prairie (burned-over) condition transforms a relatively temporary hydrologic condition (compared to a hydrologic flow regime corresponding to a forested land cover) into a permanent one.

Tools to Achieve the Standard:

1) Selection of HSPF

To comply with the standard requires use of a rainfall-runoff hydrologic simulation model that predicts runoff flow rates from a long, uninterrupted precipitation record. The Dept. of Ecology chose to use Hydrologic Simulation Program-Fortran (HSPF) as that tool. This seemed the logical choice because King County had already used calibrations of HSPF done by the USGS (see Dinicola below) for some basins in King and Snohomish Counties to develop the "King County Runoff Time Series" (KCRTS). That computer model was being used as of 1998 in King County to predict flow rates at development sites, and to size detention facilities. See pages 3-6 through 3-8 of the excerpt from the 1998 King County Surface Water Drainage Manual (reference listed above) for a brief explanation of the appropriateness of continuous runoff models for predicting runoff in western Washington. It also contains statements concerning the limitations of single-event models in predicting runoff and sizing detention facilities.

"Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington, R.S. Dinicola, USGS, Water Resources Investigations Report 89-4052, 1990.

“Validation of a Numerical Modeling Method for Simulating Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington,” R.S. Dinicola, USGS, Water-Supply Paper 2495, 2001. (Excerpts only; full copy to S. Leider)

2) Development of an easily usable HSPF model

The King County model, KCRTS, is based primarily on the calibrations done by Dinicola. The county added another land cover type of “pasture” to account for land that is cleared of vegetation, but not further disturbed through grading and filling for development purposes. There are two major challenges to implementing a flow duration standard in western Washington: a) rainfall/runoff calibrations have not been done for most watersheds; and b) the technical knowledge required to use HSPF (a FORTRAN based language) and to size detention facilities is not commonplace. Here is how Ecology managed those challenges.

a) Lack of calibrations: In addition to the watersheds studied by Dinicola, only Thurston County and Pierce County had done work to calibrate HSPF to a few small watersheds. Ecology made the decision to use what calibrations had been done for use on a generic basis throughout western Washington. These calibrations are the defaults to use unless watershed-specific rainfall runoff relationships for different land cover types are accomplished. The generic calibrations can be improved upon, but there is reason to believe that they are within a reasonable range of accuracy. First, the calibration of runoff generated by impervious surfaces should not vary among watersheds. Secondly, the combination of soil-vegetation cover land classifications for which Dinicola and King County developed calibrations are common throughout western Washington. Where the more specific calibrations have been done (Pierce County and Thurston County), the final parameters have usually been very close to those developed by Dinicola.

In any case, these calibrations represent the best information available for predicting runoff. The HSPF approach with these generalized parameters is certainly an improvement over use of the Soil Conservation Service (now Natural Resource Conservation Service) method since local calibration of published SCS curve numbers was not done. For a basic background on HSPF and its applicability for estimating runoff in western Washington please refer to the following attached document:

“Primer on the Use of Continuous Hydrologic Simulation Models for Stormwater Management,” Northwest Hydraulic Consultants, October 1998.

b) Lack of common computer skills to use HSPF and size detention facilities: Ecology realized that to implement a flow duration standard, it would be necessary to develop a user friendly computer model, similar to KCRTS, which could be used by consulting engineers throughout western Washington. Ecology contracted with Aqua Terra, Inc. to design Windows-based software to allow easy access to HSPF to estimate flows. In addition, the software had to facilitate detention and infiltration pond sizing and flow release structure design using stage-storage-discharge relationships for ponds of variable dimensions. The initial version of this model, WWHM (Western Washington Hydrology Model – Version 1) was available concurrently with the release of the stormwater manual. The model facilitated the production of runoff time series for pre-development and post-development situations. It did not include sizing of detention facilities. That had to be done by importing a spreadsheet to the program that established a stage-storage-discharge relationship for trapezoidal-shaped ponds. The WWHM and the spreadsheet are available at the Ecology website: www.ecy.wa.gov/programs/wq/stormwater/index.html

A summary of the information and assumptions used in the WWHM was inserted into the text of the stormwater manual and is attached.

"Appendix III-B: Western Washington Hydrology Model – Information, Assumptions and Computation Steps."

A summary explanation of a flow duration standard and how the model estimates compliance was written by Economic and Engineering Services, Inc. and edited by Ed O'Brien. That summary is also attached.

An updated version of WWHM (WWHM 2.0) is available for testing at the same website. This version was developed to handle more complicated drainage situations and to incorporate pond sizing and flow release structure design into the program. This should make the design process easier and more flexible.

Limitations of HSPF Modeling:

In addition to the criticisms mentioned above (primarily in Booth, 2002), there are a couple other criticisms that Ecology is aware of. First of all, the HSPF models assume that each square foot of a certain land cover and soil type (e.g., forest on till soils) within a watershed contributes the same incremental amount of runoff. That, of course, is an oversimplification. There are multiple reasons why that is not the case, including: slope and distance from a defined drainage channel. Since the models have been calibrated on a watershed scale, the expectation is that those differences should not prove problematic. Using the generic calibrations of the model, some sites will overcompensate and others will under-compensate in controlling flows. As long as development occurs roughly equally across the watershed, the use of one set of parameters for that soil/land cover condition should not be an impediment in achieving the intended goal. In any case, at the moment, we do not have information that would allow us to take these variables into account.

Secondly, the calibrations done by Dinicola still have relatively significant errors (See both references above). If the intent is to protect at least most, if not all, basins from accelerated erosion due to high flow impacts on the channel, some would argue that a factor of safety should be applied in the design of detention ponds and flow control structures. Ecology decided not to apply a factor of safety in pond design. The ponds designed to meet the flow duration standard will generally range from 60% to 300% larger than ponds that were designed under the previous standard. This rather large change in pond volumes has significant cost implications. It was decided that given the multiple levels of error and uncertainty in the basis for and the tools to meet the duration standard, it would be politically difficult to sustain an argument for a factor of safety in the design of detention facilities.

Exemptions:

The flow control requirement includes an exemption for discharges to: the Columbia River, Lakes Sammamish, Washington, and Union (King County); Silver (Cowlitz Co.), and Whatcom (Whatcom Co.). It was decided that the stormwater flows from developing areas in western Washington would not significantly affect the flow rates of the Columbia. The lakes listed above represent large waterbodies that are either directly connected to marine waters or are of sufficient size that they should adequately ameliorate the downstream impacts of increased runoff volumes into them from potential development sites. The manual includes three criteria that must be met by discharges into these waters and into any other waters that a municipality proposes for a flow control exemption.

Ecology has indicated that additional exemptions from the flow control requirement may be possible for areas draining to other large waterbodies. However, Ecology puts the burden on the local government to prove that a flow control exemption for development within a certain sub-area for the watershed of a receiving water will not result in hydrologic conditions that cause stream channel instability. Possible methods by which this may be demonstrated have not yet been identified. Initial talks with WSDOT and municipalities concerning this issue are about to begin. If the Panel wishes to have an update on this item early next year, we will provide that.

Note:

Minimum Requirement #7 includes minimum project size and flow rate increase thresholds before application of engineered flow control facilities are required. These thresholds are discussed under a separate section.

Addendum to Flow Control – Minimum Requirement #7:

The following article did not influence manual development but bears on the discussion of flow control.

38) "The Dynamics of Urban Stream Channel Enlargement," Technical Note 115, Claytor, D, Watershed Protection Techniques, Vol. 3, No. 3, March 2000

Treatment – Minimum Requirement #6

Pollution-generating Surfaces:

The stormwater manual requires treatment for runoff from pollution-generating impervious surfaces and pollution-generating pervious surfaces. Those surfaces are defined in Chapter 2, Section 2.3. Generally, those are surfaces that are considered to be significant sources of pollutants. Pollutants from these sources are generally present in "treatable concentrations." "Treatable concentrations" refers to the limitations of the available treatment technologies to make a significant reduction in the pollutant concentrations. Impervious surfaces that are considered pollution-generating include: areas with vehicular traffic, areas with "industrial activities" as defined by federal rules, metal roofs, and areas where erodible or leachable materials, wastes, or chemicals are stored. Pervious surfaces that are considered pollution-generating including those subject to use of pesticides and fertilizers, or loss of soil. See the definitions in Section 2.3 for additional details.

Surfaces that are not included as pollution-generating include residential and many commercial roofs (i.e., those not subject to venting of significant quantities of gases or dusts), bicycle pathways separated from and not subject to drainage from roads for motor vehicles.

The basis for making these distinctions includes the following sources that are attached hereto. Note that each reference is numbered. That number appears on the upper right hand corner of the attached document:

1. <u>Bellevue Urban Runoff Program</u>, Robert Pitt and Pam Bissonnette, August 1984,
   Excerpts from the Summary Report (Entire report available, if necessary)
   See "Sources of Urban Runoff Problems" on page 14, and Table 35, Figs. 8 & 9)

2. "Stormwater Threshold Issue Paper", King County internal memo by Louise Kulzer, 1994.
   See Section II, Roof Drainage, beginning on page 6

3. "Source of Urban Stormwater Pollutants Defined in Wisconsin," Note 15, Watershed Protection Techniques, Vol. 1, No. 1, Feb. 1994

4. "Is Rooftop Runoff Really Clean," Technical Note 25, Watershed Protection Techniques, Vol. 1, No. 2, Summer 1994

5. "Stormwater Pollution Source Areas Isolated in Marquette, Michigan," Technical Note 105, Watershed Protection Techniques, Vol.3, No. 1, April 1999

6. "An Introduction to Stormwater Indicators: An Urban Runoff Assessment Tool," Watershed Protection Techniques, Vol. 2. No. 2, Spring 1996. (See Table 1)

Treatment Facility Sizing:

Stormwater treatment facilities are not sized to most efficiently remove pollutants for all storm events. A stormwater facility that is designed to efficiently remove pollutants for an extremely infrequent event, say a 100-year storm event, would cost a significant amount and would be greatly under-utilized most of the time. In accordance with the technology-based requirement of pollution control statutes, it is appropriate to decide upon criteria (volumes or flow rates) for sizing treatment facilities above which could be considered unreasonable based on an incremental size increase (or cost for that size increase) per % of the annual volume effectively treated. At some storm size or flow rate, the cost becomes prohibitive to treat a few extra percent of the total annual runoff volume.

Basis for Water Quality Design Storm Volume
In developing the 1992 stormwater manual, Ecology identified the volume of runoff from a 6-month, 24-hour storm as the “water quality design storm volume.” This was based on a crude analysis of the incremental costs of pond volume versus an increase in the total amount of annual runoff that would be “effectively” treated. In this case, “effective” treatment is based upon meeting a 24-hour detention time. The summary of the cost analysis is provided herein:

7. “Appendix AI-2.1: Derivation of the Water Quality Design Storm,” from the 1992 Stormwater Management Manual for the Puget Sound Basin

For the Sea-Tac rain gauge, the 6-month, 24-hour rain volume and all smaller 24-hour rain amounts represented 91% of the annual rainfall total. So the actual target is “effective treatment” of 91% of the annual runoff volume. A survey of the rain gauges across western Washington showed that the total amount of annual rainfall represented by 24-hour rainfall amounts of 6-months duration and less ranges from 88% to 93%. (See the first two columns of Table B.1, in Appendix B of Volume I of the manual). Lacking a device for project proponents to easily identify the 91st percentile, 24-hour rainfall amount for their project site, it was decided to use the 6-month, 24-hour amount as an acceptable surrogate.

That basic cost effective analysis was supported by a more detailed cost analysis done by Herrera Environmental Consultants, 1993 (available upon request). The Herrera analysis looked at the stormwater-related costs of three example developments using the 6-month, 24-hour criteria. The reasonableness of this design storm volume is further supported by the fact that it has been in common use in the Puget Sound area for 10-years. So, it has been established as the storm size to use for technology-based stormwater treatment systems.

As a comparison, the amount of rainfall that needs treatment and a pollutant removal efficiency standard (to be discussed later in this summary) for various states, King County, and Portland are listed below. From the table, the states with the most stringent standard are those that require treatment for 90 percent of the average annual rainfall, or treatment of the 90th percentile average annual storm - Maryland, New York, and Vermont. In those states that designate a rainfall amount in inches (e.g., ½ or 1 inch), those rainfall amounts are smaller than the 6-month, 24-hour rainfall or the 91% rainfall amounts of all areas of western Washington except the areas around Port Townsend and Anacortes. So, the amount of rainfall that is targeted for treatment is generally comparable or higher in western Washington than in these other states that have adopted design storms.

Water Quality Design Storms and Pollutant Removal Standards

Alaska	Primary design criteria for runoff treatment is the use of a 2 year-6 hour storm event and the removal of particles that are 20 microns or larger.
Delaware	80% Total Suspended Solids (TSS) removal of the average annual post development loading.
Florida	80% TSS removal of the average annual post development loading. Treatment volume varies with BMP type. In all cases, at least ½ inch must be treated. 1 inch or more treated in many cases (detention). 95% TSS removal for stormwater discharges to sensitive waters, including potable supply waters, shellfish harvesting waters, and “Outstanding Florida Waters.”
Georgia	Treat the runoff from 85% of the (24-hour) storms that occur in an average year. This equates to providing treatment for runoff from a 1.2 inch rainfall. Reduce average annual post-development TSS loadings by 80%
Maryland	80% TSS removal of the average annual post development loading. Capture and treat the runoff from 90% of the average annual rainfall.
Minnesota	90% TSS removal for ½ inch of runoff from impervious area Basis: study by R.E. Pitt; Overflow rate of 1.3 x10E-4 ft/sec for a particle size distribution similar to that found in Milwaukee, WI.
Massachusetts	80% TSS removal for the design storm of ½ inch, or 1 inch in water quality sensitive areas); Achievable through treatment trains using a standardized assumed % removal efficiency for selected BMP’s. Basis: Schueler, 1996 and USEPA, 1993
New York	Treat the runoff from 90% of the (24-hour) storms that occur in an average year.
North Carolina	85% removal of TSS from the developed site.
Vermont	Capture 90% of the annual storm events, and remove 80% of the average annual post development total suspended solids load (TSS), and 40% of the total phosphorus load

Virginia	No net increase in pollutant loading from the pre-developed condition. Redevelopment projects must decrease pollutant loading by 10%.
King County	Treat runoff from a 1.4 inch event to 80% TSS removal for basic treatment; 50% total zinc removal for resource stream areas; 50% total phosphorus removal for phosphorus sensitive waters; 50% total phosphorus removal, 40% nitrate plus nitrite removal, alkalinity below 10 mg/l, and pH below 6 for sphagnum bogs. For flow-based treatment facilities treat 60% of the 2-year, 1-hour return flow rate as predicted by KCRTS to the same levels as indicated above.
Portland, Or	Treat a 0.83 inch, 24-hour storm to 70% TSS removal
Federal CZARA Program	80% TSS removal of the average annual post development loading. Based on the average annual TSS loadings from all storms less than or equal to the2-year/24-hour storm.
Other:	In a report published in 1997, Eric Livingston of the State of Florida, Rich Horner of the Univ. of Wash., and Earl Shaver of the Watershed Management Institute in Maryland reported that of 32 stormwater management programs surveyed, 17 had established performance standards for stormwater treatment. 11 of them required stormwater systems "to achieve at least an 80% reduction in the annual average post-development pollutant loading of total suspended solids discharged to fishable/swimmable waters."

In developing the new manual, Ecology assumed that effective treatment for 91% of the annual runoff volume was still reasonable. The updated manual continues to allow use of the volume of runoff predicted for a 6-month, 24-hour storm as a rough-basis for achieving the 91% target. Ecology has recently compared 24-hour runoff volume estimates produced by its HSPF-based runoff model (Western Washington Hydrology Model) to estimates produced using 6-month, 24-hour storms and curve number equations of single event models. The single event runoff volumes are 73% to 110% of the 91st percentile, 24-hour volumes predicted by the WWHM. The percentages vary within this range from rain gauge to rain gauge. Another way to state this is that the volumes of runoff predicted by the single event approach for a 24-hour rainfall of 6-month return frequency are the 82nd to 92nd percentile 24-hour runoff volumes estimated by the WWHM. So, if the WWHM more accurately predicts 24-hour runoff volumes, in most areas the pond volumes will provide somewhat less than 24 hours detention for the 91st percentile runoff volume.

Ecology has not yet decided whether it will continue to allow use of the 6-month, 24-hour storm and single event equations to estimate pond size. The limited local performance data on ponds that are sized using this approach are not sufficient to indicate that the ponds should be increased in size to achieve the 80% removal TSS removal goal.

Basis for Water Quality Design Flow Rate:
The 6-month, 24-hour storm and smaller storms were estimated to generate 91% of the annual runoff volume. That analysis worked fine for sizing volume-based treatment facilities such as wet ponds and constructed wetlands. But some facilities such as bioswales and oil/water separators require flow rates for sizing purposes. The 1992 manual assumed that facilities sized using the peak 10-minute flow rate predicted by single event hydrograph methods (e.g., the Santa Barbara Urban Hydrograph Method) for the same 6-month, 24-hour storm event and a Type 1A storm distribution (which the NRCS maps indicate is appropriate for western Washington), would result in "effectively" treating 91% of the annual runoff volume. This appears to be an incorrect assumption. Rainfall records from Olympia indicate that the peak 10 minute rainfall rate that is calculated using a 6-month, 24-hour storm and a Type 1A rainfall distribution occurs less frequently than implied. This observation is supported by flow estimates from the HSPF-based runoff models – Ecology's WWHM and King County. The peak 10 minute runoff rate from a 6-month, 24-hour storm with a Type 1A distribution occurs at about the 98th percentile flow rate predicted by the HSPF models.

The HSPF models are now being used to identify the water quality design flow rate. There are two separate rates identified – one for "off-line facilities", and one for "on-line" facilities. Both are intended to assure "effective" treatment of 91% of the average annual runoff.

Off-line facilities are those that bypass higher flow rates so as to protect the facility from washing-out previously collected solids. For those facilities, the model predicts a flow rate at which the incremental portion of flow rates above that are bypassed. 9% of the runoff file runoff volume is allowed to bypass the treatment facility. That leaves 91% of the runoff file volume to pass through the facility at or below the design flow rate. Depending on the percent imperviousness of the modeled development, the bypass begins to engage between the 72nd percentile and 80th percentile flow rates in order to ensure 91% of the runoff volume receives effective treatment.

On-line facilities are those that accept all flows. No flows are bypassed. For these facilities, the 91st percentile flow rate is the water quality design flow rate. So, the facility experiences flow rates higher than that only 9% of the time.

A more detailed explanation for the development of the water quality design volume and the water quality design flow rate is included in Appendix I-B of Volume I of the manual.

Level of Treatment:

The level of treatment that is identified as necessary in the manual depends upon the land use type and the receiving waters that the stormwater will discharge to. The step-by-step approach provided in Chapter 3 of Volume I, and repeated in Chapter 2 of Volume V is used to determine the appropriate level of treatment for a project site.

I. Background for Pollutants in Urban Stormwater

There has been a significant amount of data collection concerning the concentration of pollutants in stormwater runoff. The following summarizes the documents that influenced the Department of Ecology in establishing the treatment requirements of the manual.

8. Results of the Nationwide Urban Runoff Program, USEPA, NTIS No. PB84-185545, December, 1983.

This report summarizes USEPA's nationwide analysis of urban stormwater in the late 1970's and early 1980's. The executive summary of that report is included herein. Commonly referred to as the NURP (Nationwide Urban Runoff Program) report, its conclusions concerning stormwater characterization include:

- Heavy metals (especially copper, lead, and zinc) are the most prevalent priority pollutants with end-of-pipe concentrations exceeding water quality criteria in many instances and posing potential threats to beneficial uses.

- Coliform bacteria are present at high levels and can be expected to exceed water quality criteria even in waters with significant dilution.

- Nutrients are generally present but are not high in comparison to other sources.

- Oxygen demanding substances are present at concentrations approximating those in sewage treatment plants, and can be necessary to control in some instances.

- Total suspended solids concentrations are fairly high in comparison with sewage treatment plant discharges and should be controlled where TSS-associated water quality problems exist.

The receiving water effects conclusions of the report include:

- Frequent exceedances of heavy metals ambient water quality criteria for freshwater aquatic life are produced by urban runoff.

- Although a significant number of problem situations could result from heavy metals in urban runoff, levels of freshwater aquatic life use impairment suggested by the magnitude and frequency of ambient criteria exceedances were not observed.

- Copper, lead, and zinc appear to pose a significant threat to aquatic life uses in some areas of the country.

9) Urban Targeting and BMP Selection, USEPA, May 1990. Chapter 2.

Section 2.2 provides a summary of urban stormwater characteristics. Section 2.3 provides a summary of receiving water impacts.

10) Characterization and Source Control of Urban Stormwater Quality, Bellevue Utilities Dept., March, 1995

Bellevue's stormwater was one of 28 cities' stormwater studied in the NURP report. More recently, Bellevue completed this four year study of the water quality of its runoff. The executive summary and sections listing the key results, conclusions, and recommendations from that report are included herein. The report corroborated many of the observations of the NURP report. Its conclusions included:

- Concentrations of lead in Bellevue were dramatically reduced; an average of 10 micrograms per liter as opposed to 170 micrograms per liter. This was due to the decreased use of leaded gasoline.

- Instream concentrations of metals during storm events frequently exceeded USEPA's water quality standards for some metals.

- Acute toxicity criteria for copper were exceeded in 50 percent or more of the stormwater samples at each sampling site. In streams of basins characterized by heavily-traveled commercial and industrial land uses, the exceedance frequency was 70 to 90 percent; the exceedance frequency within the stormwater discharge itself was 100 percent.
- Storm samples for zinc exceeded USEPA's acute toxicity criteria 61 percent of the time.

- Fecal coliform concentrations exceeded the State water quality standards during most storms.

- Suspended solids were found to be far more concentrated in stormwater than in baseflow. Stormwater turbidity values taken within the streams and stormwater discharges consistently exceeded the State water quality criteria.

11) Analysis of Oregon Urban Runoff Water Quality Monitoring Data Collected from 1990 to 1996, prepared for the Oregon Association of Clean Water Agencies by Woodward-Clyde Consultants, June 1997.

This is the most comprehensive compilation of urban stormwater runoff characteristics for areas of the Pacific Northwest. The focus of the analysis was to “assess what has been learned about stormwater runoff in Oregon with respect to land use based chemical monitoring. The analytical approach was as follows: first, stormwater concentration data from monitoring stations with similar land uses were statistically compared with each other to determine if they could be combined together to characterize runoff from a specific land use; second, statistical analyses were performed on the combined data to assess whether different land uses statistically appeared to have different concentrations.

Based upon comparing monitoring results for TSS, total and dissolved copper, and total zinc, the study was able to pool data into the following land use types: in-pipe industrial, in-stream industrial, transportation, commercial, residential, and open space. The authors determined that stormwater concentrations from different land uses appeared to be statistically different from each other. Among the conclusions noted in Section 8 is that residential land use appeared to be statistically different from all other land uses. Referring to Section three of the report, residential land use showed lower pollutant concentrations than the other developed land uses, but was higher than open space.

Section 4.1 of the report compares the pollutant concentrations with water quality standards. Consistent with the information and conclusions in the NURP and Bellevue studies, the report identified frequent exceedances of the acute water quality standards for heavy metals. Dissolved copper and zinc consistently exceeded the acute water quality criteria for a majority of the monitoring stations except for open space. The percentage of exceedances tended to be higher for industrial and transportation land uses. The commercial and residential land use concentrations exceeded the criteria less frequently, but still often. Notably, the monitoring stations that were within urban creeks exceeded the copper and/or zinc criteria frequently.

Though not presented in the report, the amount by which the acute water quality criteria for dissolved copper and zinc are exceeded for each land use type can be estimated. The table below provides a summary of the factors by which the acute criteria for copper and zinc were exceeded for the four major land use types. The factors are presented for the 75% and 90% quartile values for each land use type and for three different values of hardness. The water quality criteria for the two metals varies with hardness. Surface waters in western Washington typically have a low hardness. The comparison shows that the residential concentrations do not exceed the criteria as greatly as the other land use types.

Table 1
Factor by Which Acute WQ Stds Exceeded
Dissolved Copper
Oregon Data

Percentile	**75%**			**90%**		
Hardness	**20**	**50**	**75**	**20**	**50**	**75**
Commercial	**3.2x**	**1.3x**	**1x**	**5.4x**	**2.2x**	**1.5x**
Industrial	**3x**	**1.2x**	**0.9x**	**4.6x**	**1.9x**	**1.3x**
Residential	**2x**	**0.8x**	**0.6x**	**2.4x**	**1x**	**0.7x**
Transportation	**3.2x**	**1.3x**	**1x**	**4.6x**	**1.9x**	**1.3x**

Three other sources of stormwater data were used in developing the treatment requirements. Excerpts from these sources are attached.

12) The Washington State Department of Transportation collected stormwater samples at Interstate 5 in Clark County (8 samples), and on State Route 8 west of Olympia (22 samples). The dissolved metals data were of particular interest.

13) "Lakemont Stormwater Treatment Facility Monitoring Program," Bellevue and Shapiro & Associates

Bellevue evaluated the runoff from a new residential area. 14 samples for dissolved metals in the influent were reported as part of the study of the Lakemont Stormwater Treatment Facility.

14) Design of Stormwater Filtering Systems, prepared for the Chesapeake Research Consortium, Inc., prepared by Richard Claytor and Tom Schueler of The Center for Watershed Protection, December 1996.

A table of stormwater pollutant concentrations from different urban source areas was compiled from various sources by Tom Schueler.

15) 2000 – 2001 Annual Data Summary Report, California Department of Transportation, CTSW-RT-02-002

This document was published after publication of the manual. Table 8 from that report is attached. For the list of pollutants, the table provides the range, mean, standard deviation and % detection for highways with more than and less than 30,000 average daily trips (cars passing the sampling location). Using the mean hardness value given in the table, the acute water quality standards for copper, lead, and zinc have been hand written into the margins. The actual number of exceedances could only be computed by knowing the hardness and metals concentrations for each sample. But the data roll-up provides the overall message that exceedances of criteria for copper, zinc, and lead occur frequently.

Also note that the concentrations are higher for the higher ADT highways. This result is consistent with the fact that cars are the primary source of the metals in the runoff.

II. Basic Treatment:

The basic treatment requirement is the technology-based level of treatment identified in the manual. It is the minimum level of treatment that would apply to a site regardless of its discharge location. The basic treatment requirement focuses on removal of suspended solids. 80% total suspended solids (TSS) removal is the design goal. If the raw stormwater influent is less than 100 mg/l, the goal is to achieve 20 mg/l TSS or less in the effluent. These goals are not effluent limits that are expected to be achieved at all sites using basic treatment technology, but are an indication of the level of treatment that can be achieved at many sites if the proper conditions are present. The goals are used to decide what treatment technologies are added to the Menu of technologies that can be selected. The 80% removal and 20 mg/l goals (as well as other goals for Enhanced Treatment and Phosphorus Treatment) are based upon information provided from the following sources from which we have attached excerpts:

16) National Pollutant Removal Performance Database for Stormwater Management Practices, Center for Watershed Protection, August 1997 (entire volume available upon request)

17) "Comparative Pollutant Removal Capability of Urban BMPs: A Reanalysis," Technical Note 95, Watershed Protection Techniques, Vol. 2, No. 4, June 1997 (mostly a summary of the above reference)

18) Evaluation of Highway Runoff Pollution Control Devices, National Technical Information Service, PB97-138481, December 1996 (entire volume available upon request)

19) National Stormwater BMP Database, USEPA & American Society of Civil Engineers (ASCE), http://www.bmpdatabase.org/. Note: This database is significantly more extensive than it was at the time of manual development

20) Urban Targeting and BMP Selection, USEPA, May 1990. Chapter 3
Note: The "wet pond" facilities in the Western Washington manual roughly correspond to a Vb/Vr ratio of 3.

21) "Irreducible Pollutant Concentrations Discharged from Urban BMPs," Technical Note 75, Watershed Protection Techniques, Vol. 2, No. 2, Spring 1996

22) "Pollutant Removal Dynamics of Three Wet Ponds in Canada," Technical Note 114, Watershed Protection Techniques, Vol.3, No. 3, March 2000 (Note: The wet ponds in the Ecology manual provide more or equivalent storage as that specified in the article for a "level 1 fishery (excellent habitat) 80% sediment removal."

The types of treatment (wet ponds, biofiltration, wetlands) specified as acceptable for meeting the Basic Treatment requirement are commonly used for new development throughout the United States. The types of projects to which it applies are identified in the treatment selection process of Volume I, Chapter 4, Step 6 (also at Volume V, Chapter 2, Step 6). Those project types and the reason why Ecology considered basic treatment as adequate are summarized below:

- ***Residential projects not in the watershed of a water that has phosphorus restrictions:***

  The Oregon data set indicated that stormwater runoff from residential areas generally has lower concentrations of suspended solids and heavy metals compared to other land use types. The amount of dilution needed to bring the concentrations of metals below the water quality **acute** criteria (see explanation under the Enhanced Treatment section below) are substantially less than for other land use types. The 90th percentile value of dissolved copper in the Oregon data set ranged from 1x to 2.4x the water quality acute criteria assuming a hardness of 50 and 20 mg/l respectively. Most of the ambient receiving water data collected in western Washington is within the 20 to 50 mg/l hardness range (ambient monitoring results from many locations throughout Western Washington is available upon request).

  The data set from the new Lakemont residential development in Bellevue exhibited even lower concentrations of dissolved copper and zinc. The report indicates that the water quality standards for dissolved copper, zinc, and lead were not exceeded by any of the samples.

  Though some of the treatment types listed as acceptable for meeting the basic treatment requirement probably achieve only nominal dissolved metals removal (0% to 20%; see discussion under Enhanced Treatment), it was decided that in most discharge situations the acute standards for zinc and copper would not be violated in the receiving waters as a result of stormwater discharges from residential developments. Even in the case of the 90th percentile value from the Oregon data set, if the receiving water had sufficient dilution available to reduce the concentration roughly in ½, the standard would be met. Therefore, basic treatment should be the default level of treatment for residential sites.

- ***Project sites discharging directly to salt waters or major receiving waters listed in Appendix I-C.:***

  Salt waters and the large natural waters listed in Appendix C have substantial amounts of water draining from undeveloped areas that is available for dilution of stormwater discharges. Stormwater discharges are unlikely to cause violations of water quality standards except for localized violations of turbidity and bacteria. Marine sediment management standards could also be violated as the solids in raw stormwater discharges are deposited in low energy environments. Therefore, basic treatment facilities, which will reduce the turbidity and the sediment in the discharges is appropriate.

- ***Project sites that drain to streams that are not fish-bearing, or to waters not tributary to fish-bearing streams:***

The protection and propagation of fish life is a Clean Water Act goal. Fish life is also the most visible non-human beneficial use of fresh waters that society generally would agree is desirable to maintain and to protect from the effects of pollutants. Where fresh waters do not support fish life (e.g., steep drainages into salt water), the biological implications of water quality standards violations are generally not as much of a concern to natural resource agencies or to the public. Therefore, where such waters occur, the basic treatment standard will apply.

- ***Landscaped areas of industrial, commercial, and multi-family project sites, and parking lots of industrial & commercial sites dedicated solely to employee parking and without other pollution generating sources.***

These are areas that generally should not generate any more pollutants than residential areas because of a lack of intensive vehicle traffic. Therefore, a similar treatment requirement – Basic Treatment – should apply.

III. Enhanced Treatment

An explanation of the water quality criteria for metals and their applicability to stormwater discharges helps set the stage for explaining the Enhanced Treatment requirements of the manual.

i) Acute versus Chronic Water Quality Criteria
The water quality **acute** criteria for metals that are commonly found in urban stormwater - copper, zinc, lead, and cadmium – are 1-hour average concentrations not to be exceeded more than once every three years on average. The water quality **chronic** criteria for those metals are 4-day average concentrations not to be exceeded more than once every three years on the average. Most stormwater professionals around the nation agree that the acute criteria are applicable to stormwater dischargers (e.g., see page 4-1 of the Oregon data – reference # 11 above). The chronic criteria, which are lower concentrations, are not seen as applicable because of their 4-day scope. However, in western Washington and Oregon, extended storm events can occur in the winter. Reference #23a provides a table that compares storm durations around the USA. Note the probability duration and exceedance probability data for Seattle and Portland indicate that storm events of four days or more are more likely in those areas than any of the other reported locations. Still, a more in-depth analysis of the rainfall data and actual runoff durations would be needed to determine whether the chronic criteria are germane to stormwater discharges.

ii) Applicability of Water Quality Criteria
Some have argued that there should be further investigation into whether the water quality criteria should apply to stormwater discharges. See the 1984 NURP report (reference #8, page 8), and the 1995 Bellevue report (reference #10, pages

28 & 29). Regardless of the merits of those arguments, USEPA has not provided any guidance or rules regarding different water quality criteria for stormwater discharges. Without any guidance to the contrary, Ecology must take actions to gain compliance with its existing water quality standards. In addition, Ecology argues that the data provided above would indicate that the acute criteria for metals are germane to stormwater discharges and should factor into decisions made in developing generic guidance for treatment practices to apply to stormwater discharges.

There are also concerns raised concerning the relative toxicity of urban stormwater. Reference #23 provides information in regard to the relative toxicity of stormwater from different source areas.

23b) "Urban Stormwater Toxic Pollutants: Assessment, Sources, and Treatability," Pitt, R., R. Field, M. Lalor, and M. Brown, Water Environment Research, Vol. 67, No. 3, 1995.

iii) Total versus Soluble metals and Available Treatment Performance Data
Another issue is whether total metals or dissolved metals should be the focus of concern. Soluble (dissolved) metal concentrations are thought to be a better indicator of potential aquatic toxicity than total metals (which includes metals that are tightly bound to particles). There are very limited data available on the ability of commonly used stormwater treatment facilities to remove dissolved metals. There are appreciable data available in regard to treatment performance in removal of total metals. But the removal mechanisms are primarily related to solids removal. This statement is taken from page 21 of the <u>National Pollutant Removal Performance Database for Stormwater Best Management Practices</u> (reference #16): "A quick review of the few BMP studies that examined soluble metals suggests that while removal is usually positive, it is almost always lower than total metals removal." That same reference indicates median removal rates of 50 – 80% for total zinc (excluding dry ponds and open channels which are not used in the stormwater manual), and 40 – 60% for total copper (excluding open channels).

The limited data on dissolved metals removal includes studies with the following results:

Reported Percent Removals by Treatment Type

	Wet Ponds	**Sand Filters**	**Biofiltration Swale**	**Constructed Wetland**
Copper	**53/24/31**	**0/19**	**21**	**-1**
Zinc	**34/48/48/ 48**	**51/77**	**-25/30**	
Lead	**66**	**50**		**-5**

Generously assuming that the Basic Treatment facilities listed above could achieve a 30% removal of dissolved copper, here is the factor by which the acute standard for copper would be exceeded by the land use types in the Oregon cities' data set (reference # 11)

Factor by Which Acute WQ Stds Exceeded
Dissolved Copper
After 30% Removal
Oregon Data

Percentile	**75%**			**90%**		
Hardness	**20**	**50**	**75**	**20**	**50**	**75**
Commercial	**2.2x**	**0.9x**	**0.65x**	**4x**	**1.6x**	**1.1x**
Industrial	**2x**	**0.6x**	**0.6x**	**3x**	**1.3x**	**0.9x**
Residential	**1.5x**	**0.55x**	**0.4x**	**1.7x**	**0.7x**	**0.5x**
Transportation	**2.2x**	**0.9x**	**0.65x**	**4x**	**1.6x**	**1.1x**

The above table indicates that at hardness levels around 20 mg/l, which is not uncommon in western Washington, the 90^{th} percentile concentrations for copper, after 30% removal, still exceed the acute standard by a factors of 3 to 4 times for the industrial, commercial, and transportation land uses. At a hardness of 50, which is only substantially exceeded by 11% of about 430 hardness measurements taken throughout western Washington, the treated stormwater from the same three aforementioned land uses would exceed the copper acute standard by 1.3 and 1.6 times.

In order to not cause a violation of the copper (and probably the zinc) acute standards, a substantial amount of natural background water, low in dissolved metals, would have to be available. In streams draining urban and urbanizing areas, where most new development and redevelopment occur, the data do not indicate that a large capacity exists to dilute the metals. The 1995 Bellevue study (reference #10) reported frequent exceedances of the acute criteria for metals within the receiving water. The samples taken within the urban creeks in the Oregon study (reference #11) exceeded the copper and/or zinc criteria frequently.

The available data indicate that the acute criteria for dissolved copper and zinc are frequently exceeded in raw stormwater runoff from industrial and commercial sites, and urban roads and highways. Most of the reported dissolved metal concentrations in stormwater are from composite samples that are composed of aliquots taken over multiple hours. Because the acute criteria are a one-hour concentration, using the concentrations reported in the literature cited above most likely under-represents the actual frequency of exceedances of the acute criteria.

With this information, Ecology decided that it could no longer presume that application of any of the basic treatment types from the 1992 manual, which are commonly used, would generally result in compliance with the acute water quality criteria within the receiving waters. The agency decided it needed to take additional steps to reduce the probability of exceeding the criteria. It decided to establish a new treatment category, referred to as Enhanced Treatment.

The Enhanced Treatment Requirement is a presumptive, water quality-based level of treatment. The goals set for Enhanced Treatment are 80% total suspended solids removal, and "a higher rate of dissolved metals removal than Basic Treatment facilities." Due to the sparse data available concerning dissolved metals removal in stormwater treatment facilities, a specific performance goal could not be established. Instead, Ecology relied on available nationwide and local data (as reported in the national databases and the Lakemont study), and knowledge of pollutant removal mechanisms of treatment facilities to develop a list of options that could result in a significant reduction of dissolved metals concentrations.

Where the available literature had inconsistent or conflicting data on the performance of certain treatment types in dissolved metals removal, Ecology erred on the side of including a particular practice in the Enhanced Treatment menu. This was considered necessary in order to have a sufficient range of options available. Some options have implementation requirements such as large space (e.g., wetlands) or head restrictions (e.g., sand filters) that can make them unusable at certain locations.   An example of conflicting performance data is the information concerning the effectiveness of sand filters in removing dissolved metals. A large sand filter is listed as a stand alone option, and basic sand filters are listed as a component of 4 treatment train options in the Enhanced Treatment menu.

Ecology hopes, but does not know, that the BMP options specified in the Enhanced Treatment menu will perform in the 50% to 80% removal range for dissolved metals. Even at those efficiencies, violations of the acute standards will occur in areas with low hardness waters and receiving waters that are dominated by urban stormwater runoff during storm events. However, the frequency of the incidence of dissolved metals violations will decrease. Ecology is unaware of any treatment options that will more reliably reduce dissolved metals concentrations to the point that we could say with confidence that the acute standards will not be violated in most discharge situations.

Ecology will take actions in the following areas to close the information gaps in regard to dissolved metals:

> i) Ecology will encourage and possibly require testing (through NPDES permits) of the commonly used stormwater treatment options, and the options identified in the Enhanced Treatment Menu to get more definitive information on their ability to remove dissolved metals.

ii) Ecology has developed, and will continue to improve, a testing protocol so that the data collected on treatment facilities is of high quality and sufficient from which to make judgments concerning performance. Ecology will cooperate with other states and national organizations such as ASCE & USEPA in this endeavor.

iii) Ecology will encourage the suppliers of new treatment technologies to use the testing protocol to assess performance for dissolved metals removal.

iv) Ecology will propose (through NPDES permits) more testing of dissolved metals in receiving waters in order to better assess the extent to which the water quality criteria for dissolved metals are exceeded.

A final note on this subject: Ecology's establishment of the Enhanced Treatment requirement follows on the heels of the establishment of a Resource Stream Protection requirement in the 1998 King County stormwater manual. King County established this Resource Stream protection requirement to protect what it considered to be important fishery resources in streams that still had high quality habitat. The county publishes a map which shows the areas that the requirement applies to. The intent of the requirement is to achieve 50% reduction of the total metals content of stormwater runoff. King County applies it to any type of development, including residential development, which drains into a "resource stream."

Ecology's Enhanced Treatment requirement differs from the County's in three ways:

i) Ecology targets dissolved metals rather than total metals; and

ii) The requirement does not apply to residential developments. Ecology thought that the data were not as convincing that residential developments posed a substantial risk of violations of water quality criteria for metals; and

iii) The requirement applies to all fresh waters that are fish-bearing or that are tributary to fish-bearing waters. This is a broader geographic use of the requirement than King County's. The Clean Water Act does not discriminate among waters that have "important fisheries resources" or unimportant fisheries resources. Wherever the beneficial use of fish life exists, or existed as of 1977, those uses must be protected. The Clean Water Act also does not discriminate based upon the present condition of the habitat. If the fish are present (or were present as of 1977) though the habitat condition is poor, new stormwater discharges cannot worsen the situation by discharging toxic materials that violate water quality criteria intended to protect fish life.

IV. Phosphorus Treatment

The Phosphorus treatment requirement is a generic approach to reducing the phosphorus loading from new development and redevelopment projects. It is not required in any discharge situation until a government with jurisdiction identifies use of the Phosphorus

Menu as necessary in order to help achieve a phosphorus loading goal or a concentration goal in a receiving water. Phosphorus removal requirements can be set by local, state, or federal governments as a tool to meet Total Maximum Daily Load plans, or Lake Management Plans.

The treatment options in the menu are intended to achieve 50% reduction of total phosphorus, and 80% removal of total suspended solids.

This requirement is not controversial.

V. Oil Control

The oil control requirement is a generic, technology-based requirement. Oil and grease, other petroleum-based substances, and polycyclic aromatic hydrocarbons in crankcase oil and vehicle emissions are semi-volatile organic compounds (SVOC's) that are common in urban stormwater. They are washed off of surfaces subject to vehicle traffic – roads, parking lots, and driveways. Some of these SVOC's are associated with particulates. Their presence in the environment can be reduced through suspended solids removal. Others are soluble or insoluble. The insoluble portions can form a sheen that is aesthetically unpleasing, limit air exchange, and be toxic to certain species. Fish studies have shown toxicity in the 1 to 10 Total Petroleum Hydrocarbon range, and embryo studies have shown impacts in the parts per billion range. A number of studies on the impact of crude oil have been done as a result of the Exxon Valdez spill. The following website provides information on the results of those efforts.

24) NOAA Auke Bay Laboratory website: www.afsc.noaa.gov/abl/OilSpill

Two articles of potential interest from the Auke Laboratory document sensitivity of salmonid embryos to weathered crude oil. Mortality and growth reductions due to aqueous PAH concentrations are reported. Those articles are listed below but are not attached. They can be obtained upon request.

Carls, M.. et al, "Sensitivity of Fish Embryos to Weathered Crude Oil: Part I. Low-Level Exposure During Incubation Causes malformations, Genetic Damage, and Mortality in Larval Pacific Herring," Environ. Toxicol. Chem., 1999, 18(3):481 – 493

Heintz, Ron A. et al, "Sensitivity of Fish Embryos to Weathered Crude Oil: Part II: Increased Mortality of Pink Salmon Embryos Incubating Downstream from Weathered Exxon Valdez Crude Oil," Environ. Toxicol. Chem., 1999, 18(3): 494-503

The following article provides a summary of information on semivolatiles in stormwater. It focuses primarily on SVOC's in sediment, but some information on water and sources is included.

25) A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater, Lopes, T.J., and Dionne, S.G., 1998, USGS Open File Report 98-409

Unfortunately, short of use of dispersion techniques, the state of the art in oil removal in stormwater is oil/water separators, sand filters, and absorbent materials. These technologies are only effective at reducing concentrations to somewhat below 10 parts per million. Therefore, the stormwater manual only specifies use of oil-removing technologies where concentrations of oil can often be above that level.

The areas where application of oil control devices are appropriate are identified in Volume V, Chapter 3, Section 3.2, page 3-2 (These are repeated in Volume I, Chapter 4, page 4-6). Ecology followed King County's decisionmaking on this requirement. The 1998 King County Surface Water Design Manual lists the same areas as those in the Ecology manual. The primary basis for the requirement is summarized in the following paper:

26) "High Use/Oil Control Decision Paper," King County internal memo by Jenny Glaus

Addendum to Treatment – Minimum Requirement #6

The attached information was not used in development of the manual, but is provided as additional relevant information to the Panel.

37) "The Toxicity and Chemical Composition of Urban Stormwater Runoff," Hall, Ken J., & Anderson, Bruce, C., Canadian Journal of Civil Engineering, Vol. 15, 1988

Thresholds

The stormwater manual uses project size to trigger size-appropriate stormwater manual requirements. The first set of thresholds are shown in Figures 2.2 and 2.3. The following text will go through the flow chart step-by-step and provide the rationale for each threshold.

Explanation of Figure 2.2 – Flow Chart for Determining Requirements for New Development

Step 1: Does the site have 35% or more of existing impervious coverage?
This step is intended to identify those sites that have substantial development on them already. Projects on those sites are considered redevelopment, and therefore subject to a different set of thresholds (Figure 2-3). Most commercial sites with development easily have over 35% impervious area. This threshold also prevents a large parcel in the rural area that has had a residence and some farm-related buildings (barn, chicken coop) and that has been sub-divided and scheduled for development from being considered a re-development site.

Because most single family home lots have less than 35% impervious coverage re-modeling of those lots will only be potentially subject to stormwater requirements for their new impervious surfaces through this flow chart. This will make home remodeling projects manage stormwater runoff from their new surfaces so that increased impacts are minimized. It will not have them providing stormwater management for replaced impervious surfaces. Ecology and local governments consider it problematic to encourage a proliferation of engineered facilities on residential sites. It is difficult to ensure future proper operation and maintenance because access for inspections can be very difficult. It will be more cost efficient and more reliable for solutions to existing impervious surfaces (even those being replaced) to be managed on a cumulative basis through retrofitting of public facilities.

Ecology is considered an addendum to this figure that will require application of Minimum Requirements #1 - #5 to any replaced impervious surfaces on project sites that exceed the new impervious (5,000 sq. ft.) threshold or the land disturbing thresholds (3/4 acre and 2.5 acre thresholds). These are requirements that don't necessarily require an engineer and which will provide some mitigation of the replaced impervious surfaces with practices that won't require inspection by local government inspectors in the future.

Step 2: Does the project add 5,000 sq. ft. or more of new impervious surface?
This is the first threshold or screen that is used to identify projects that may have to comply with all of the Minimum Requirements. Exceeding this threshold could result in the construction of professionally engineered stormwater structures (subject to additional thresholds within Minimum Requirements #6 & #7).

The earliest local recorded use of the 5,000 square foot threshold is in a 1977 areawide planning study done for Snohomish and King Counties and the City of Everett. That document recommends use of a 5,000 sq. ft. threshold as a trigger for drainage review of projects and application of engineered treatment and flow control structures. Long-time stormwater planners say that threshold was selected to exempt most individual home construction projects from drainage review. This seems probable but is not substantiated in written records that the department was able to find.

It is either a coincidence or a supporting reason that at 5,000 sq. ft. of impervious area, SBUH modeling predicts a 0.1 cfs increase in the 100-year flood frequency (See reference #26) for a site in the western King or Snohomish Counties. As further explained in Step 3 below, operation of orifices that are sized to meet flow control standards at flow changes less than 0.1 cfs presents reliability problems. The 1977 planning document where the 5,000 sq. ft. threshold first surfaces locally, used SBUH modeling to predict runoff and size flow control facilities.

Ecology began writing its first stormwater manual in the late 1980's. Ecology reviewed existing planning documents, other states' stormwater guidance, and local stormwater manuals in developing that first manual. The 5,000 square foot threshold for application of engineered treatment and flow control facilities was selected for use in that manual.

In its latest update of its stormwater manual, King County did a review of whether the 5,000 square foot threshold was supportable from the aspect of constructing treatment facilities. See Reference #2 above. The conclusion of the County's staff was that it was still a reasonable threshold to use for treatment facilities.

In Ecology's update of its stormwater manual, it asked for but did not receive objections to continued use of this threshold from the Volume I Advisory Committee. By that time, it had become a mostly accepted threshold.

Step 3: Does the project convert ¾ acres or more of native vegetation to lawn or landscaped areas, or convert 2.5 acres or more of native vegetation to pasture?
If the answer to Step 2 above is no, this is the next question for determining requirements for a project. These land disturbing areas correspond to a 0.1 cubic feet per second change in the 100-year flood frequency from a site as estimated by an HSPF model using rainfall from the SEA-TAC rain gauge. Smaller changes in the 100-year flood frequency would require use of circular orifices that are smaller than ½ inch diameter to meet the flow duration standard. The opinion of local government regulators was that orifices smaller than that size plug too frequently – e.g., a single maple seed can lodge in the orifice. This makes the detention pond non-functional from the time of plugging or partial plugging, until someone inspects the pond for proper operation and maintenance. Based on the information available to us, no local governments have sufficient operation and maintenance budgets that would guarantee frequent inspections. So, this flow change was adopted as a lower threshold below which detention ponds would not be necessary.

The 0.1 cfs increase is not used directly in this table for practicality of implementation reasons. Ecology did not want to establish a threshold that would require all projects, even very small projects, to run the HSPF model to determine whether they needed treatment and flow control structures. It takes some expertise to know whether a 0.1 cfs increase would be caused by a project. Alternatively, it is easy for anyone to check whether the area sizes of ¾ acres or 2.5 acres are exceeded.

The 0.1 cfs increase will correspond to slightly different disturbed areas for areas of western Washington that have significant differences in their rainfall patterns. Ecology is open to local governments establishing different size thresholds based upon use of an approved HSPF model.

Reference #27 is a chart produced by King County that shows estimated increases in predicted 100-year flood frequencies from new impervious surfaces that replace native forest cover on till soils (the most common in the Puget Sound basin). In the three far left hand columns, the runoff flow rate from a pre-developed forested condition, the runoff flow rate from a post-developed impervious area, and the flow rate difference between the two rates are listed. These flow rates are as predicted by King County's version of HSPF – the King County Runoff Time Series (KCRTS). The next three columns list the flow rates for the same three situations, but as predicted by the Santa Barbara Urban Hydrograph (SBUH) technique. The amount of impervious surface applicable for each set of figures is recorded in the middle of the page. The column on the right side of the page lists example situations that would create that much impervious surface.

Scanning down the impervious surface totals to 11,000 sq. ft. and reading across to the KCRTS figures should show a predicted flow rate increase of 0.11 cfs. Impervious area of 10,000 sq. ft. produces an increases of about 0.1 cfs.

Step 4: Does the project have 2,000 sq. ft. or more of new, replaced, or new plus replaced impervious surfaces?
and
Step 5: Does the project have land-disturbing activities of 7,000 sq. ft. or more?
These thresholds are intended to capture most individual home construction projects and small commercial & industrial projects of similar size. If the questions are answered positively, Minimum Requirements #1 - #5 apply. These requirements may not require the services of a consulting engineer. They are primarily requirements that are seen as being reasonable for smaller projects to comply with. They will have some positive effect in reducing the pollutant loading and the high flow increases caused by small projects.

The incentive to regulate stormwater for projects as small as this comes from observations made by local governments concerning the cumulative stormwater impacts (localized flooding as well as stream erosion) from exempting individual single family home construction. Booth and Jackson (**Reference #27)** discussed the implications of a King County threshold that exempted projects of 0.5 acre impervious surface. The conclusion was that so many new projects would not be subject to flow control regulations that the aquatic system would be severely degraded.

28) "Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation," Booth, Derek B., and Jackson, C. R., Journal of the American Water Resources Association, Oct. 1997, Vol. 33, No. 5

Step 6: Apply Minimum Requirement #2
If the project does not exceed the 2,000/7,000 sq. ft. thresholds, it is still considered appropriate to have that project responsible for controlling erosion during construction. The local stormwater or building ordinance does not have to require submission of a formal drainage plan. However, it should require all projects to take practical steps to control erosion on-site.

One way to implement such a provision is for the local governments to attach a single sheet flyer that explains the erosion control requirement and displays appropriate small site practices such as temporary covering of the disturbed area and routing stormwater away from the disturbed area.

Final Note:
If the Panel is interested in reviewing thresholds adopted by other states, Ecology will provide examples from states that are proactive in stormwater management.

Explanation of Figure 2.3 – Flow Chart for Determining Requirements for Redevelopment

Steps 1 and 2: Top Half of the Flow Chart down to "Next Question:"
Up to this point in the flow chart, redevelopment projects have the same thresholds and requirements as new development projects. The rationale is the same as for new development projects.

Remaining Steps: Bottom Half of the Flow Chart:
The remaining sections of the flow chart are intended to identify when Minimum Requirements #6 through #10 apply to the "replaced" impervious surfaces of the project. The thresholds for this decision are policy-based, not science-based. They are judgment calls based upon interpretations of when it is reasonable to bring the replaced impervious surfaces up to current stormwater standards.

If the panel wants a more detailed discussion of this section. Ecology will provide it.

Water Quality Treatment Thresholds – Table 2.1

Once it is determined, per Figure 2-2 or Figure 2-3, that a project is subject to Minimum Requirement #6 – Treatment – the project site drainage must be evaluated and compared to the thresholds in Table 2.1. That table identifies requirements based upon the total amount of “pollution-generating impervious surfaces” (PGIS) and “pollution-generating pervious surfaces” (PGPS) within each “threshold discharge area.” See a previous explanation of the terms PGIS and PGPS. A Threshold Discharge Area” is an area of a project site that drains to a single natural location or multiple natural locations that combine within ¼ mile downstream. Refer to the diagrams on page 2-7 of Volume I.

This extra step is intended to make sure that treatment facilities are constructed only where it is reasonable to do so. A project may have exceeded the initial thresholds of Figures 2-2 or 2-3, but because of the drainage patterns on the site, collecting runoff from 5,000 square feet of PGIS at one location may not be possible without extraordinary measures. Pumping stormwater or extensive site grading to facilitate gravity flow of all the PGIS and PGPS to one location to meet the treatment requirements violates Minimum Requirement #4. Minimum Requirement #4 requires preservation of natural drainage patterns to the maximum extent practicable.

Even on very large projects, some smaller areas may naturally drain a different direction from the majority of the project. In those instances, where the 5,000 sq. ft. of PGIS, and the ¾ acre of PGPS are not exceeded in the smaller “threshold discharge area”, only Minimum Requirement #5 must be met. Minimum Requirement #5 requires the use of flow dispersion and infiltration techniques, and soil amendments.

If flows leave the project site at two separate locations must combine within ¼ mile, the two areas are considered one Threshold discharge area. This distance is a practical guide that is intended to prevent site developers from creating multiple discharge points from their project site in order to circumvent treatment and flow control requirements. In most cases, they will not have the ability to change drainage patterns beyond their project boundaries.

Flow Control Treatment Thresholds: Table 2.2

Once it is determined, per Figure 2-2 or Figure 2-3, that a project is subject to Minimum Requirement #7 – Flow Control - the project site drainage must be evaluated and compared to the thresholds in Table 2.2. The areal thresholds in the table – 10,000 sq. ft. impervious surface; ¾ acre conversion to lawn/landscape; 2.5 acres conversion to pasture – are all associated with a 0.1 cfs increase in the 100 year flood frequency for projects in western King County. Those areal thresholds can be adjusted by local governments to correspond to a 0.1 cfs increase for their local area. The 0.1 cfs increase is listed as a separate threshold because a project may be under each of the areal thresholds but the cumulative changes could put it over the 0.1 cfs increase. This will require professional services. Because the initial thresholds of Figures 2-2 and 2-3 have screened out the smaller projects, Ecology considers it reasonable at this juncture to require professional services to run the HSPF flow model.

Similar to Table 2.1 of the treatment requirement, all of these thresholds are applied to the project site by threshold discharge area.

Note: The use of "threshold discharge areas" is a concept taken from the 1998 King County Surface Water Drainage Manual. It has been in use for four years, so it is an implementable concept, though it adds a layer of complexity to determining project requirements.

Impacts of Urbanization

The following five sections, designated 1.7.1 through 1.7.5 are a reprint from Chapter 1 of Volume 1 of the Stormwater Management Manual for Western Washington. These sections are followed by an addendum that provides additional information and references

1.7.1 Background Conditions

Prior to the Euro-American settlement, western Washington primarily was forested in alder, maple, fir, hemlock and cedar. The area's bountiful rainfall supported the forest and the many creeks, springs, ponds, lakes and wetlands. The forest system provided protection by intercepting rainfall in the canopy, reducing the possibility of erosion and the deposition of sediment in waterways. The trees and other vegetative cover evapotranspirated at least 40% of the rainfall. The forest duff layer absorbed large amounts of runoff releasing it slowly to the streams through shallow ground water flow.

1.7.2 Hydrologic Changes

As settlement occurs and the population grows, trees are logged and land is cleared for the addition of impervious surfaces such as rooftops, roads, parking lots, and sidewalks. Maintained landscapes that have much higher runoff characteristics typically replace the natural vegetation. The natural soil structure is also lost due to grading and compaction during construction. Roads are cut through slopes and low spots are filled. Drainage patterns are irrevocably altered. All of this results in drastic changes in the natural hydrology, including:

- Increased volumetric flow rates of runoff;
- Increased volume of runoff;
- Decreased time for runoff to reach a natural receiving water;
- Reduced ground water recharge;
- Increased frequency and duration of high stream flows and wetlands inundation during and after wet weather;
- Reduced stream flows and wetlands water levels during the dry season; and
- Greater stream velocities.

Figure 1.1 illustrates some of these hydrologic changes. As a consequence of these hydrology changes, stream channels are eroded by high flows and can lose summertime base flows. Increased flooding occurs. Streams lose their hydraulic complexity. Habitat is degraded and receiving water species composition is altered as explained below.

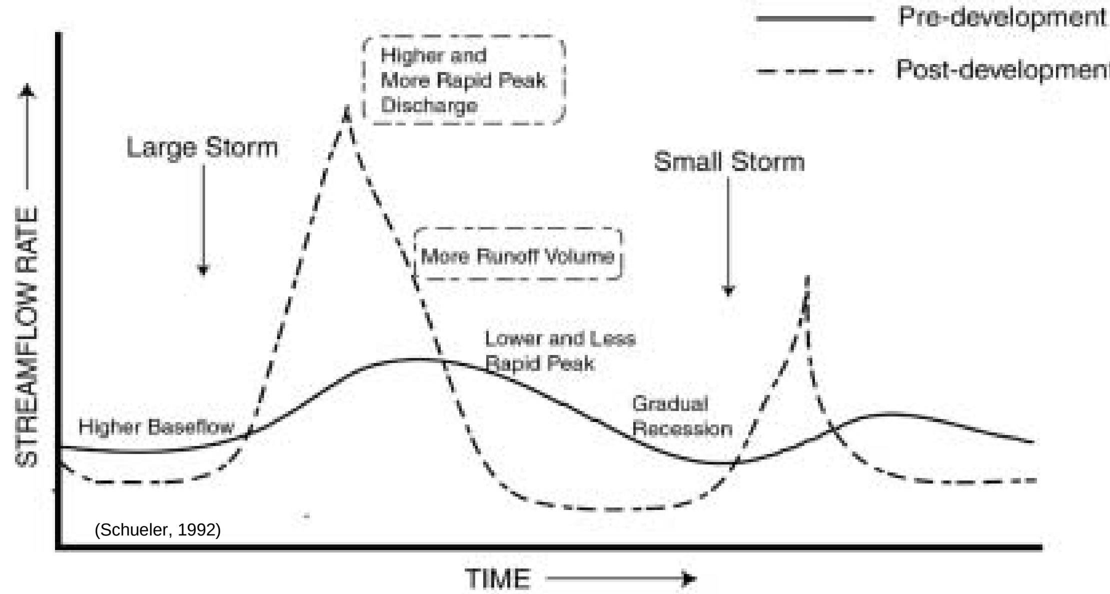
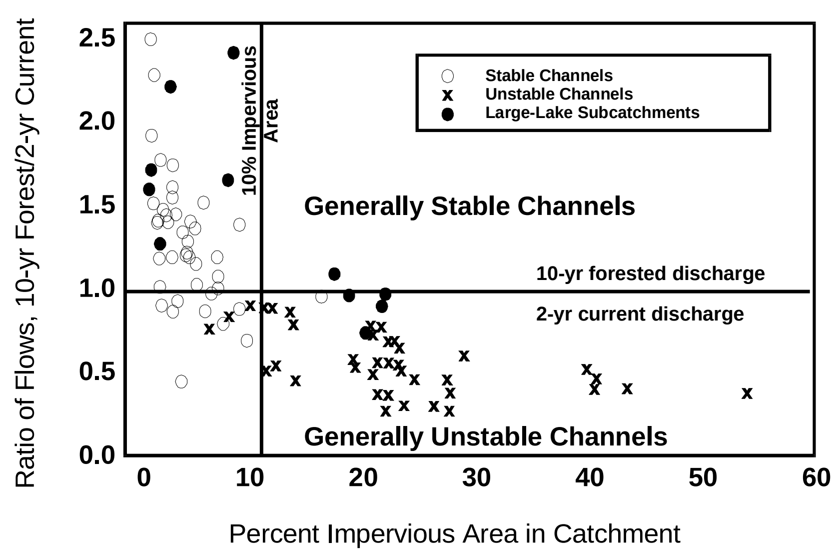


Figure 1.1 – Changes in Hydrology After Development

Figure 1.2 (Booth and Jackson, 1997 (Reference #28)) illustrates one observed relationship between the level of development in a basin (as measured by effective, not total, impervious area), the changes in the recurrence of modeled stream flows, and the resultant streambank instability and channel erosion. These data show that even a crude measure of stream degradation, "channel instability," shows significant changes at relatively low levels of urban development. More sensitive measures, such as biological indicators (see section 1.7.4), document degradation at even lower levels of human activity.

Figure 1.2 - Channel Stability and Land Use:



Hylebos, East Lake Sammamish, Issaquah Basins

1.7.3 Water Quality Changes

Urbanization also causes an increase in the types and quantities of pollutants in surface and ground waters. Runoff from urban areas has been shown to contain many different types of pollutants, depending on the nature of the activities in those areas. Table 1.1, from an analysis of Oregon urban runoff water quality monitoring data collected from 1990 to 1996, shows mean concentrations for a limited number of pollutants from different land uses. (Strecker et al, 1997 (Reference #11))

Table 1.1 Mean Concentrations of Selected Pollutants in Runoff from Different Land Uses

Land Use	TSS mg/l	Total Cu mg/l	Total Zn mg/l	Dissolved Cu mg/l	Total P mg/l
In-pipe Industry	194	0.053	0.629	0.009	0.633
Instream Industry	102	0.024	0.274	0.007	0.509
Transportation	169	0.035	0.236	0.008	0.376
Commercial	92	0.032	0.168	0.009	0.391
Residential	64	0.014	0.108	0.006	0.365
Open	58	0.004	0.025	0.004	0.166

Note:
In-pipe industry means the samples were taken in stormwater pipes. Instream industry means the samples were taken in streams flowing through industrial areas. Samples for all other categories were taken within stormwater pipes.

The runoff from roads and highways is contaminated with pollutants from vehicles. Oil and grease, polynuclear aromatic hydrocarbons (PAH's), lead, zinc, copper, cadmium, as well as sediments (soil particles) and road salts are typical pollutants in road runoff. Runoff from industrial areas typically contains even more types of heavy metals, sediments, and a broad range of man-made organic pollutants, including phthalates, PAH's, and other petroleum hydrocarbons. Residential areas contribute the same road-based pollutants to runoff, as well as herbicides, pesticides, nutrients (from fertilizers), bacteria and viruses (from animal waste). All of these contaminants can seriously impair beneficial uses of receiving waters.

Regardless of the eventual land use conversion, the sediment load produced by a construction site can turn the receiving waters turbid and be deposited over the natural sediments of the receiving water.

The pollutants added by urbanization can be dissolved in the water column or can be attached to particulates that settle in streambeds, lakes, wetlands, or marine estuaries. A number of urban bays in Puget Sound have contaminated sediments due to pollutants associated with particulates in stormwater runoff.

Urbanization also tends to cause changes in water temperature. Heated stormwater from impervious surfaces and exposed treatment and detention ponds discharges to streams with less riparian vegetation for shade. Urbanization also reduces ground water recharge, which reduces sources of cool ground water inputs to streams. In winter, stream temperatures may lower due to loss of riparian cover. There is also concern that the replacement of warmer ground water inputs with colder surface runoff during colder periods may have biological impacts.

1.7.4 Biological Changes

The hydrologic and water quality changes result in changes to the biological systems that were supported by the natural hydrologic system. In particular, aquatic life is greatly affected by urbanization. Habitats are drastically altered when a stream changes its physical configuration and substrate due to increased flows. Natural riffles, pools, gravel bars and other areas are altered or destroyed. These and other alterations produce a habitat structure that is very different from the one in which the resident aquatic life evolved. For example, spawning areas, particularly those of salmonids, are lost. Fine sediments imbed stream gravels and suffocate salmon redds. The complex food web is destroyed and is replaced by a biological system that can tolerate the changes. However, that biological community is typically not as complex, is less desirable, and is unstable due to the ongoing rapid changes in the new hydrologic regime.

Significant and detectable changes in the biological community of Puget Sound lowland streams begin early in the urbanization process. May *et al* (1997) reported changes in the 5-10% total impervious area range of a watershed.

29) "Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion," May, C., et al, Watershed Protection Techniques, Vol. 2, No. 4, June 1997.

Figure 1.3 from May *et al* (1997, reference #29)) shows the relationship observed between the Benthic Index of Biotic Integrity (B-IBI) developed by Kleindl (1995) and Karr (1991), and the extent of watershed urbanization as estimated by the percentage of total impervious area (% TIA). Also shown in the figure is the correlation between the abundance ratio of juvenile coho salmon to cutthroat trout (Lucchetti and Fuerstenberg 1993) and the extent of urbanization. *(Note: These references, not are not attached to this summary. The full references are listed in Volume 1 directly after Chapter 4. The references can be supplied upon request.)*

The biological communities in wetlands are also severely impacted and altered by the hydrological changes. Relatively small changes in the natural water elevation fluctuations can cause dramatic shifts in vegetative and animal species composition.

In addition, the toxic pollutants in the water column such as pesticides, soaps, and metals can have immediate and long-term lethal impacts. Toxic pollutants in sediments can yield similar impacts with the lesions and cancers in bottom fish of urban bays serving as a prime example.

A rise in water temperature can have direct lethal effects. It reduces the maximum available dissolved oxygen and may cause algae blooms that further reduce the amount of dissolved oxygen in the water.

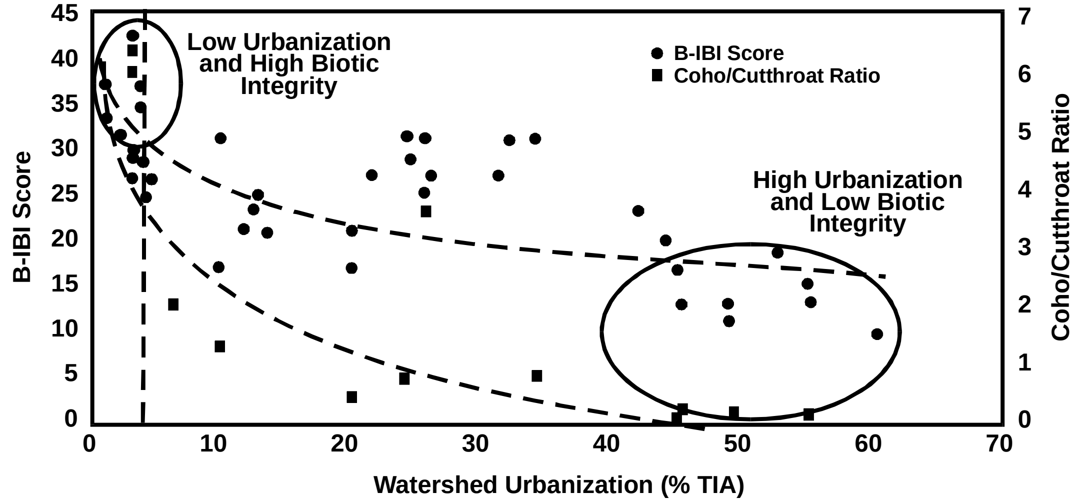


Figure 1.3 - Relationship Between Basin Development and Biotic Integrity in Puget Sound Lowland Streams

1.7.5 The Role of Land Use and Lifestyles

The manual's scope is limited to managing the surface runoff generated by a new development or redevelopment project. The manual does not intend to delve deeply into site development standards or where development should be allowed. Those are land use decisions that should not be directed by this stormwater manual. The manual applies after the decision to develop a site has been made. The manual can provide site development strategies to reduce the pollutants generated and the hydrologic disruptions caused by development.

The engineered stormwater conveyance, treatment, and detention systems advocated by this and other stormwater manuals can reduce the impacts of development to water quality and hydrology. But they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions. Ecology understands that despite the application of appropriate practices and technologies identified in this manual, some degradation of urban and suburban receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems. Unless development methods are adopted that cause significantly less disruption of the hydrologic cycle, the cycle of new development followed by beneficial use impairments will continue.

In recent years, researchers (May et al, 1997, (Reference #29)) and regulators (e.g., Issaquah Creek Basin and Nonpoint Action Plan, 1996, not attached hereto)) have speculated on the amount of natural land cover and soils that should be preserved in a watershed to retain sufficient hydrologic conditions to prevent stream channel degradation, maintain base flows, and contribute to achieving properly functioning conditions for salmonids. There is some agreement that preserving a high percentage (possibly 65 to 75%) of the land cover and soils in an undisturbed state is necessary. To achieve these high percentages in urban, urbanizing, and suburban watersheds, a dramatic reduction is necessary in the amount of impervious surfaces and artificially landscaped areas to accommodate our preferred housing, play, and work environments, and most significantly, our transportation choices.

Surfaces created to accommodate cars comprise the greatest portion of impervious areas in land development. Therefore, to make appreciable progress in reducing impervious surfaces in a watershed, we must reduce the density of our road systems, alter our road construction standards, reduce surface parking, and rely more on transportation systems that do not require such extensive impervious surfaces (rail, bicycles, walking).

Reducing the extent of impervious surfaces and increasing natural land cover in watersheds are also necessary to solve the water quality problems of sediment, temperature, toxicants, and bacteria. Changing public attitudes toward chemical use and preferred housing are also necessary to achieve healthy water ecosystems.

Until we are successful in applying land development techniques that result in matching the natural hydrologic functions and cycles of watersheds, management of the increased surface runoff is necessary to reduce the impact of the changes. Figure 1.3 illustrates that significant biological impacts in streams can occur at even low levels of development associated with rural areas where stormwater runoff has not been properly managed. Improving our stormwater detention, treatment, and source control management practices should help reduce the impacts of land development in urban and rural areas. We must also improve the operation and maintenance of our engineered systems so that they function as well as possible. This manual is Ecology's latest effort to apply updated knowledge in these areas. The question yet to be answered is whether better management – including improved treatment and detention techniques – of the increased surface runoff from developed areas can work in combination with preservation of high percentages of natural vegetation and soils on a watershed scale to yield a minimally altered hydrologic and water quality regime that protects the water-related natural resources.

In summary, implementing improved engineering techniques and drastic changes in where and how land is developed and how people live and move across the land are necessary to achieve the goals in the federal Clean Water Act - to preserve, maintain, and restore the beneficial uses of our nation's waters

Addendum to Impacts of Urbanization

The above discussion was written to summarize the impacts of urbanization for manual readers. Additional information that may be of interest to the panel is included below. This information did not influence the development of the manual.

Urban hydrology and stream rehabilitation:

30) “Stream Health After Urbanization,” Finkenbine, J.K. et al, Journal of the American Water Resources Association, October 2000, Vol. 36, No. 5

31) “Discussion No. 98161D” concerning “Stream Health After Urbanization,” Hartley, D., Jackson, C.R., and Lucchetti, G., Journal of the American Water Resources Association, June 2001, Vol. 37, No. 3.

32) “Reply to Discussion,” No. 98161D, Finkenbine, J.K., et al, Journal of the American Water Resources Association, June 2001, Vol. 37, No. 3.

These articles are concerned with the physical habitat changes caused by urbanization and what measures may be appropriate for stream rehabilitation. The authors do not agree on the use of detention ponds as a tool to aid in stream rehabilitation. This has been pointed to by some stormwater professionals as a reason why detention should not be required at new development and redevelopment in urbanized watersheds. Ecology does not agree with that conclusion. New development will cause increased energy in a stream channel; even in channels that have been hydrologically changed by preceding urbanization. Watersheds that have had some amount of new development in recent years, probably have not re-stabilized. It is appropriate to mitigate for the high flow impacts of the new development. It is a separate question re what may be the best strategies to mitigate for the impacts of long-standing urbanization.

33) “Hydrologic Trends Associated with Urban Development for Selected Streams in the Puget Sound Basin, Western Washington,” Konrad, Christopher, and Booth, Derek, Water Resources Investigations Report 02-4040, U.S. Geological Survey, 2002

This project evaluated annual stream flow statistics from 10 streams to identify possible hydrologic trends associated with urban development and to evaluate the effect of record length on errors in trend analysis.

Urbanization Impacts on Salmonids and Strategies for Stream Rehabilitation and Protection

34) “Watershed Urbanization and the Decline of Salmon in Puget Sound Streams,” Horner, Richard and May, Christopher, Unpublished,

This article is an extension of Reference # 29.

Retention of Natural Vegetation:

35) “Regional Study Supports Natural Land Cover Protection as Leading Best Management Practice for Maintaining Stream Ecological Integrity,” Horner, Richard and

May, Christopher, presented at the First South Pacific Conference on Comprehensive Stormwater and Aquatic Ecosystem Management, 1999.

This paper emphasizes the importance of natural land cover protection. It also acknowledges the limited role of structural BMPs, such as those in the stormwater manual, in controlling the impacts of urbanization.

36) “Forest Retention, Runoff Response, and Implications for Salmonids,” Hartley, David, Memorandum prepared for the Tri-County ESA Stormwater Group; May, 2000

The memo estimates the hydrologic benefits of retaining mature forest cover during the land development process.

Stormwater Websites

http://www.stormwatercenter.net/
The **Stormwater Manager's Resource Center** is designed specifically for stormwater practitioners, local government officials and others that need technical assistance on stormwater management issues. Created and maintained by the Center for Watershed Protection, the SMRC has everything you need to know about stormwater in a single site:

http://www.cwp.org/stormwater_mgt.htm
Founded in 1992, the **Center for Watershed Protection** is a non-profit 501(c)3 corporation that provides local governments, activists, and watershed organizations around the country with the technical tools for protecting some of the nation's most precious natural resources: our streams, lakes and rivers. The Center has developed and disseminated a multi-disciplinary strategy to watershed protection that encompasses watershed planning, watershed restoration, stormwater management, watershed research, better site design, education and outreach, and watershed training.

http://depts.washington.edu/cuwrm/
The Center for Urban Water Resources Management is an interdisciplinary research center at the University of Washington, whose mission is to develop new and more effective ways for managing the consequences of land development on the Pacific Northwest's water resources through applied research and technology transfer. Established in 1991 to help coordinate research and training needs on behalf of the region's water resource agencies, a broad range of local, regional, and Federal agencies has continued to support a variety of projects. In addition to traditional grant-funded research, the Center maintains several additional programs including the Storm Water Technologies Research and Training Fellowship for graduate-student research; a quarterly newsletter distributed to over one hundred individual, agency, and industry subscribers; an in-house reference library and publication distribution service of recent water-resource research reports; and co-sponsorship of the College of Engineering's continuing education program in stormwater management.

http://www.bmpdatabase.org/

This database provides access to BMP performance data in a standardized format for over 190 BMP studies conducted over the past fifteen years. The database may be searched and/or downloaded on this Web site, and is also available on CD-ROM. Additional BMP studies are currently being prepared for the database. The database was developed by the Urban Water Resources Research Council (UWRRC) of ASCE under a cooperative agreement with the US Environmental Protection Agency.

The primary purpose of this database is to report on the effectiveness of urban storm water BMPs using rigorous, scientifically valid data and information. The database was initiated by reviewing the literature for all existing BMP performance studies, screening the quality of those studies using rigorous standards developed by the ASCE and recording those BMP effectiveness studies that had valid results. Over 800 studies were reviewed and compiled. Of those many were screened out for invalid data, lack of necessary measurements or the lack of other information. As ASCE concluded-- there are many BMP effectiveness and performance studies in the literature, but very few done with good scientific and engineering AQ/QC. The rigorous screening criteria that ASCE developed to evaluate all the past studies were also intended as guidelines for researchers conducting BMP effectiveness studies in the future to help ensure good quality data would be collected for the database.

This BMP effectiveness database has been functioning for several years now and is acquiring more BMP study inputs and as a result is becoming more useful. Ecology referred to the site when preparing drafts of its manual. The Principle Investigators on the project were:

Ben Urbonas, Denver Urban Drainage and Flood Control District (303)
455-6277
Jonathan Jones, Wright Water Engineers (303) 480-1700
Eric Strecker, GeoSyntec Consultants (503) 222-9516

http://www.smartgrowth.org/library/built.html

In recent years interest has grown in Smart Growth as a mechanism for improving environmental quality. In *Our Built and Natural Environments*, the U.S. Environmental Protection Agency (EPA) summarizes technical research on the relationship between the built and natural environments, as well as current understanding of the role of development patterns, urban design, and transportation in improving environmental quality. *Our Built and Natural Environments* is designed as a technical reference for analysts in state and local governments, academics, and people studying the implications of development on the natural environment.

http://yosemite.epa.gov/R10/WATER.NSF/webpage/Storm+Water?OpenDocument
This is the USEPA-Region X homepage on stormwater. You'll find lots of information in regard to NPDES stormwater programs, and a link to the USEPA headquarters stormwater homepage. If you click on the "Useful Links" in the USEPA-Region X homepage, it will take you to a page that provides links to many local, state, and federal government stormwater sites. It also includes links to non-profit sites. Note that there are a number of links to recently released stormwater manuals by east coast states.

http://www.epa.gov/owow/nps/urbanmm/index.html
National Management Measures to Control Nonpoint Source Pollution from Urban Areas is a draft technical guidance and reference document published by USEPA for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on the best available, economically achievable means of reducing pollution of surface and ground water from urban areas. The document is considered a draft. USEPA is taking comments on it until December 9, 2002. They intend to publish a final. The contact person is Rod Frederick of USEPA at frederick.rod@epa.gov.

At this website, clicking on the link for "Management Measure 5: New Development Runoff Treatment" opens USEPA's draft guidance document for treatment and flow control measures. Clicking on the link for "Management Measure 6: Site Development" opens USEPA's guidance for site development to minimize hydrologic disruption and pollutant generation. This is the subject area that Ecology's stormwater manual does not pursue in as much detail because it starts to get into land use management. Better land use management techniques are necessary for aquatic natural resource protection, but should not be mandated by a stormwater manual.